

High Current Switching

Analog switches are sometimes required to conduct appreciable amounts of current, either continuous, or instantaneous - such as charging or discharging a capacitor. For best reliability, it is recommended that instantaneous current be limited to less than 80mA peak and that average power over any 100 millisecond period be limited to $\leq I^2 \times R_{ON}$ (absolute maximum derated power- quiescent power). Note that R_{ON} increases at high current levels, which is characteristic of any FET switch. Switching elements may be connected in parallel to reduce R_{ON} .

Op Amp Switching Applications

When analog switches are used either to select an op amp input, or to change op amp gain, minor circuit rearrangements can frequently enhance accuracy. In Figure 1, R_{ON} of the input selector switch adds to R_1 , reducing gain and allowing gain to change with temperature. By switching into a non inverting amplifier (b), gain change becomes negligible. Similarly, in a gain switching circuit, R_{ON} is part of the gain determining network in (c), but has negligible effect in (d).

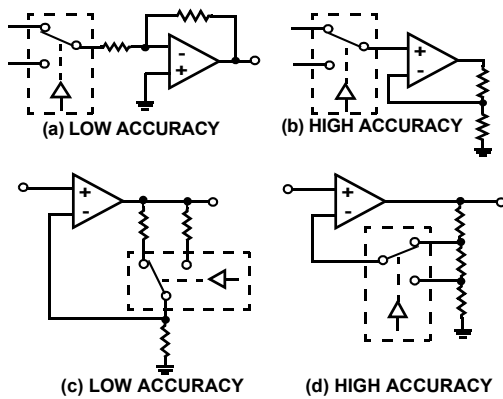


FIGURE 1. OP AMP SWITCHING APPLICATIONS

Switching Spikes And Charge Injection

Transient effects when turning a switch off or on are of concern in certain applications. Short duration spikes are generated (Figure 2 (a)) as a result of capacitive coupling between digital signals and the analog output. These have the effect of creating an acquisition time interval during which the output level is invalid even when little or no steady state level change is involved. The total net energy (charge injection) coupled to the analog circuit is of concern when switching the voltage on a capacitor, since the injected

charge will change the capacitor voltage at the instant the switch is opened (Figure 2 (b)).

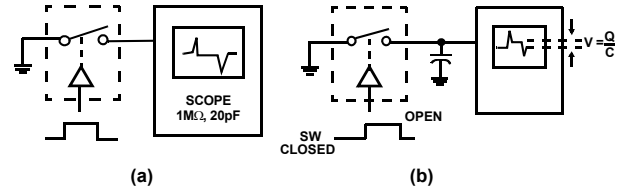


FIGURE 2. SWITCHING SPIKES AND CHARGE INJECTION

Charge injection is measured in picocoulombs; the voltage transferred to the capacitor is computed by:

$$V = \frac{\text{Charge (pC)}}{\text{Capacitance (pF)}}$$

Both of these effects are, in general, considerably less for CMOS switches than for equivalent resistance JFET or PMOS devices, since the gate drive signals for the two switching transistors are of opposite polarity. However, complete cancellation is not possible, since the N and P channel switches do not receive gate signals quite simultaneously, and their geometries are necessarily different to achieve the desired DC resistance match.

In applications where transients create a problem, it is frequently possible to minimize the effect by cancellation in a differential circuit, similar to Figure 3.

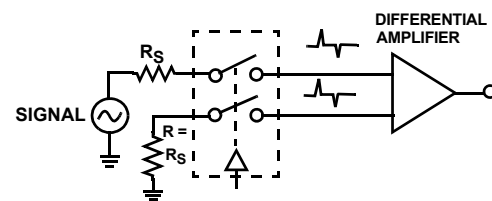


FIGURE 3. DIFFERENTIAL CIRCUIT

Among the analog switches, the HI-201 is the best from the transient standpoint, having turn-on spikes of about 100mV peak, 50ns width at the 50% point, and charge injection at turn-off of about 20 picocoulombs. Transients of the HI-504X series are several times higher.

High Frequency Switching

When considering a switching element for RF or video type information, two factors must be watched: attenuation vs. frequency characteristics of an ON switch, and feedthrough (isolation) vs. frequency characteristics of the OFF switch.

Optimizing the first characteristic requires a low $R_{ON} \times C_D$ product, and the second a low value of C_{DS} (OFF).

One approach is to use the 30Ω switch types of the HI-5040 series.

Figure 4 illustrates three circuit configurations; (a) is a simple series switch, (b) is a series-shunt configuration to reduce feedthrough, and (c) is an SPDT selector configuration with series-shunt elements. A $1k\Omega$ load is illustrated, which might be the input impedance of a buffer amplifier; a lower load resistance would improve the response characteristics, but would create greater losses in the switch and would tend to distort high level signals.

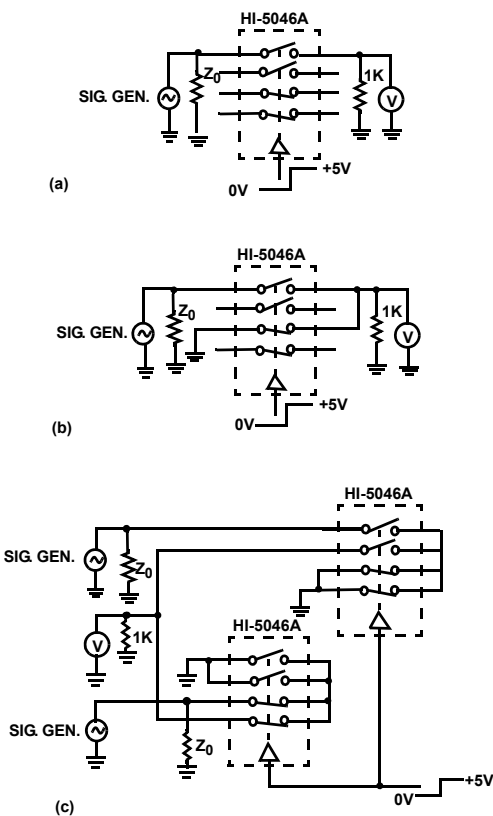


FIGURE 4. CIRCUIT CONFIGURATIONS

Figure 5 shows ON and OFF frequency response for each of the above configurations. Arbitrarily, we will define useful frequency response as the region where ON losses are less than 3dB and OFF isolation is greater than -40dB.

The simple configuration (a) has excellent ON response, but OFF isolation limits the useful range to about 1MHz (the data sheet indicates -80dB isolation at 100kHz, but this is measured with 100Ω load, which accounts for the 20dB difference).

The circuit in (b) shows a good improvement in isolation produced by the low impedance of the shunt switch. The useful range is about 10MHz, which could also be achieved in a simple SPDT 2-switch selector if source impedances are very low.

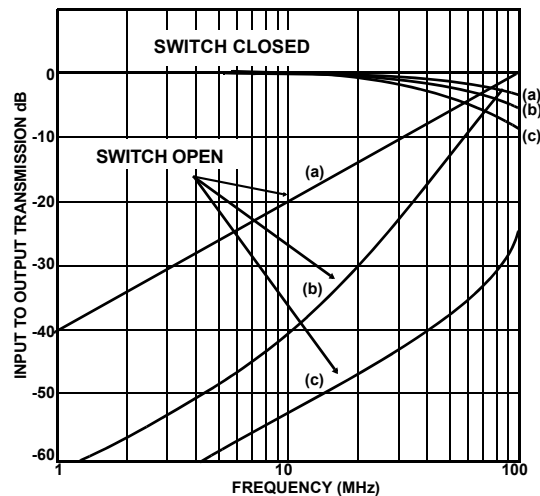


FIGURE 5. ON AND OFF FREQUENCY RESPONSES

The selector switch in (c) has excellent characteristics, both ON and OFF curves indicating 40MHz useful response. Additional switches connected to the same point would reduce the ON response because of added shunt capacitance, but this could be eliminated by feeding separate summing amplifier inputs.

For many applications, a better approach is to use the HI-524 monolithic wideband CMOS multiplexer. This device utilizes a series-shunt multiple switching network to achieve low crosstalk without sacrificing or compromising other operational parameters. As shown in Figure 6, each channel comprises three CMOS FET switch gates, with two in series and the third shunted to ground. The two series switches ensure both a high off isolation and low feed-through capacitance. The shunt grounding switch, closed automatically by the control logic when its corresponding series pair are open, shunts nonselected channels to ground, thus minimizing crosstalk. With this circuit topology, crosstalk is typically -60dB at 10MHz.

A buffer amplifier is used with the HI-524 for high frequency applications, due to its higher ON resistance, and should offer sufficient bandwidth and slew rate to avoid degradation of the anticipated signals. For video switching, the HA-5033 and HA-2542 offer good performance plus $\pm 100mA$ output

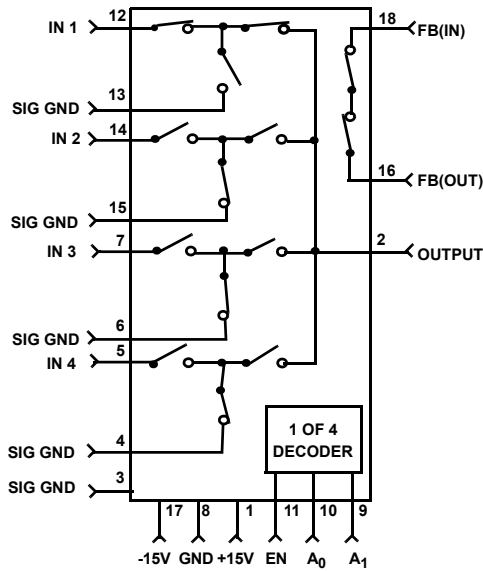


FIGURE 6. HI-524 MONOLITHIC WIDEBAND CMOS
MULTIPLEXER

current for driving coaxial cables. For general wideband applications, the HA-2541 offers the convenience of unity gain stability plus 90ns settling (to $\pm 0.1\%$) and $\pm 10V$ output swing. Also, the HI-524 includes a feedback resistance for use with the HA-2541. This resistance matches and tracks the channel ON resistance, to minimize offset voltage due to the buffer's bias currents.

Careful layout is, of course, important for high frequency switching applications to avoid feedthrough paths or excessive load capacitance.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
 3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
 5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
 6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
 7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
 8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
 10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
 11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338